COMMERCIAL HYBRID SNCR/SCR DEMONSTRATION

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ABSTRACT

The U.S. Department of Energy (DOE), Electric Power Research Institute (EPRI), Pennsylvania Electric Energy Research Council, (PEERC), New York State Electric and Gas and GPU Generation, Inc. are jointly funding a demonstration to determine the capabilities of a Hybrid SNCR/SCR (Selective Non-Catalytic Reduction/Selective Catalytic Reduction). The demonstration site is at GPU Generation's Seward Unit #5 (147 MW) located in Seward Pennsylvania. The demonstration will begin in late October of 1997 and will continue for a period of one year. The DOE funding is being provided through Grant No. DE-FG22-96PC96256 with T.J. Feeley as the Project Manager.

The project will demonstrate the operation of a Hybrid SNCR/SCR NO_x control process on a full scale coal fired utility boiler. The hybrid technology is expected to provide a cost effective method of reducing NO_x while balancing capital and operating costs. The process also provides a method for staging the NO_x reduction performance and costs to suit the needs of the utility.

An urea based SNCR system is currently in operation on Seward Unit #5 and the ammonia slip from the SNCR will be used as the reducing agent for the hybrid catalyst. The project goals are: demonstrate that hybrid technology is capable of achieving greater than 55% reduction from baseline NO_x emissions while maintaining less than 2 ppm ammonia slip at the inlet to the air heaters; maintain fly ash marketability; verify the performance capabilities of two different types of catalysts (plate and monolith); determine the cost benefit and applicability of hybrid post combustion technology; and reduce forced outages due to ABS fouling of the air heaters. Since the demonstration will begin in October of 1997 and continue for a period of one year operating data is not available. Therefore this paper will describe the methodology of the system design and construction.

INTRODUCTION

Under the first phase of NO_x controls mandated by the Clean Air Act Amendments of 1990, low NO_x burners were required by Title IV, while overfire air was required in Pennsylvania in order to comply with Title I (RACT). Additional technologies such as reburn, SNCR and deeper air staging have been further developed and demonstrated. In some instances, such as the SNCR on Unit #5 at Seward Station, they have been installed and are being used to satisfy the requirements of RACT. Phase II provisions for Title I and Title IV will lower the allowed emissions in 1999 and 2000 respectively. This will required additional capital expenditure in order to comply. For selected units, a combination of technologies may provide a cost effective means for compliance. Hybrid combinations of SNCR and SCR are a flexible method for moderated to deep reductions of NO_x at cost ranges typically below those of a full scale SCR retrofit. By combining the two technologies, the result is a more cost effective technology than the sum of the parts and it provides the best characteristics from each technology.

OBJECTIVE

The existing SNCR system on Seward Unit #5, is presently being operating in an inefficient mode in order to minimize the effects of air heater fouling. The fouling is a result of excessive ammonia slip created by the SNCR system, which combines with the SO_3 in the flue gas to form ammonium bisulfate. The normal controllable slip level is 5 ppm. However, based on the extensive operating data, it has been determined that an ammonia slip level below 2 ppm is required to control the air heater fouling. The installation of a Hybird SNCR/SCR will strip the ammonia from the flue gas to an acceptable level, and allow the existing SNCR system to be operated in a more optimum mode so that it can potentially meet the new NO_x reduction requirements of Phase II of the CAAA. In addition, there are other objectives for this project that will interest utilities faced with the Phase II requirements. They are as follows:

- Provide proof of concept of the Hybrid process with eastern bituminous coal
- Determine the cost/benefit and applicability of Hybrid post combustion technology
- Verify that overall NO_x reduction of at least 55% from a 1990 baseline can be achieved
- Maintain an ammonia slip level of less than 2 ppm at an end of a three year catalyst life
- Achieve a projected catalyst life of at least 3 years
- Maintain flyash marketability
- Verify the performance capabilities of the two different types of catalyst (monolithic and plate/wash coat)
- Develop a flue gas conditioning system that can be used in conjunction with an ammonia monitor.

APPROACH

A full scale demonstration of the Hybrid SNCR/SCR technology will be performed by GPU Generation, Inc. at their Seward Station Unit #5. The system has been designed and the necessary components are in the process of being fabricated. Modifications required for the installation of the Hybrid SNCR/SCR system are scheduled to be performed during an outage beginning on September 8, 1997. The baseline testing of the system will occur during early November with additional testing after 6 months and 1 year. The unit is capable of 147 MW gross generating capacity and has an existing urea based SNCR system in operation since June of 1995. The baseline NO_x emissions were between 0.70 and 0.75 lb/MMBTU. The SNCR system reduced the emissions from the baseline noted above to 0.45 lb/MMBTU while minimizing the ammonia slip level to approximately 5ppm. At this level of ammonia slip, ammonium bisulfate fouling of the air heaters prevented continuous operation of the system. Additional tuning, operational changes and control changes were made to minimize or eliminate ammonia spikes and other intermittent high levels of ammonia slip. Based on the data that was generated during this time period, it was determined that an ammonia slip level of less than 2 ppm was required to minimize air heater fouling to an acceptable level. This value of ammonia slip was the key to the design of the Hybrid SNCR/SCR for Seward Unit #5.

Due to the air heater fouling problem with the existing system, the unit is currently being operated at reduced efficiency (approximately 0.5 lb/MMBtu) to produce less than 2 ppm ammonia slip. As a result, as much as 75% of the chemical is injected into the furnace where utilization is relatively low. The remaining chemical is injected behind the pendant superheater tubes located above the furnace arch. Injection is performed with multi-nozzle lances which provide good chemical distribution and high chemical utilization.

During the design and development of this project, consideration was given to the following parameters:

- **Ammonia slip control - SNCR to SCR** - The urea which is used as the reductant, undergoes thermal decomposition to generate ammonia that reacts with the NO_x in the flue gas. Correct placement of the droplets of reagent allows the generated ammonia to encounter NO_x in an environment which provides the correct kinetics for the reduction of NO_x to occur. As with any chemical oxidation reduction reaction, the reaction is not complete. The ammonia which does not react with the NO_x in the flue gas is used as the reductant feed for the SCR. Control of this phenomenon allows the proper amount of ammonia slip to pass to the SCR providing additional NO_x reduction and control of the ammonia slip to the air heaters.

- **Gas Temperatures** - Gas temperatures into the catalyst must be maintained above 575°F in order to avoid ammonium bisulfate formation in the voids of the catalyst, thus avoiding catalyst deactivation. Relatively low temperatures are normal for full load operation on this unit. The average temperatures are 623°F and 602°F for the ‘A’ and ‘B’ side respectively. A static mixer and gas crossover piping will be installed to help to more evenly distribute the temperature and to raise the low temperatures along the wall. In addition, the side walls will be inspected for any major air in-leakage and repaired as required during the scheduled outage in September.

- **Erosion** - Both catalyst type (monolith and solid metal /wash coat) has its own unique strategy for combating the erosive effects of flyash and high velocity. The monolith is equipped with a hardened leading edge which absorbs the initial erosive effect. The solid metal substrate allows for erosion of the leading edges to the base metal which in turn act as flow straightening devices to manage the angle of attach of the ash on the balance of the material.

- **Available Space** - The available space for the catalyst reactor vessel was considered and final placement was determined to be in the two sections of ductwork between the economizer outlet and the air heater inlet. The maximum amount of space was used between the existing duct location and the outside wall of the boiler house. In addition, the ducts were expanded to the outside of the existing duct location. The available area was sufficient to achieve control of the expected ammonia slip. However, it did limit the reduction capabilities to those used for this project.

- **Flue Gas Velocities** - The face velocity of the flue gas entering the catalyst is approximately 19-20 ft/sec. This is approximately 50-100% greater than velocities used for full scale SCR installations. A flow model study was performed to balance the flows into the catalysts to within ±5% of theoretically equal, ensure flow is normal to the catalyst face and to equalize the flow distribution through each catalyst with a RMS deviation less than 10% of the mean velocity.

- **Ash Loading** - The ash loading between the two ductworks are not balanced due to the conditions created by the four corner tangential-fired boiler. The dust loading between the ‘A’ and ‘B’ ducts are 3531 and 5563 lb/hr respectively. Even though the imbalance exists, it is not out of the normal ash loading range expected by the catalyst vendors. During the flow model study is was discovered that the ash loading was being concentrated to the front portion of each duct, particularly due to the turning vanes installed to straighten the flow. This problem was eliminated with the installation of dust deflection baffles.

- **Ammonia Distribution** - Maximum performance in a full-scale SCR requires uniform ammonia to NO_x ratios across the face of the catalyst. The ammonia slip to the SCR in the Hybrid SNCR/SCR, however, will be significantly lower than the NO_x at all points in the flow. Performance degradation due to the variations in NH_3 concentrations will, therefore, be greatly reduced. Control of the NH_3 distribution is being accomplished with the multi-nozzle lances.

- **SO_2 to SO_3 Conversion** - Because of current air heater sensitivities, the catalytic rate of SO_3 generation is important. The conversion rate is limited to less than 1% for one vendor and less than .5% for the other vendor. The catalyst vendors have specified a minimum operating temperature of 575°F above which ammonium salt formation and deposition on the catalyst face will be avoided.

TECHNOLOGY DESCRIPTION

Hybrid Background

Hybrid SNCR/SCR NO_x reduction systems can be engineered in many different configurations depending upon the level of overall NO_x reduction desired and the configuration of the existing unit. Both factors combined lead to differences in catalyst dimensions and, therefore, catalyst contributions to the total capital requirement. The different types of hybridized SNCR/SCR can be fit into one of three major categories. The catalyst configurations that are used in conjunction with a SNCR system are as follows:

- Catalytic air heater baskets
- “In Duct” SCR with existing or expanded duct dimensions
- Combination of air heater and “In Duct” SCR

Additional variations to the above list can also be made by either using ammonia from the SNCR system as the reductant for the SCR or by including a separate ammonia injection distribution header ahead of the SCR. For the purposes of this paper, the term “Hybrid” will be reserved for a combination of a SNCR and “expanded duct” SCR with the reductant for the catalyst coming from the SNCR.

A survey[1] was conducted on the above combined technologies and listed the potential benefits and drawbacks of combining the technologies. It primarily reported from a technological feasibility viewpoint where a specific requirement for SCR is presumed. It is important, however, to view the potential application of hybridized SNCR/SCR from an economic standpoint, particularly in the case where combustion modification have already been employed. Items that need to be considered when performing such a review are:

- Desired level of NO_x reduction
- NH_3 constraints
- Volume of catalyst that can be installed based on existing plant physical constraints and face velocity requirement from the catalyst vendors
- Available pressure drop with existing fans
- What structural steel and ductwork modifications are required to support the catalyst?
- Guaranteed life of catalyst at specified ammonia slip levels
- NH_3 distribution and flow requirements
- Are NO_x reduction requirements incremental?
- Existing NO_x emissions baseline
- What is the remaining life of subject unit?

It can easily be seen that the total capital requirement for the catalyst retrofit will increase as the catalyst size and retrofit complexity increases. The key to minimizing lifecycle NO_x reduction costs is to find the appropriate balance between annualized capital charges and operating costs for the remaining life of the system. The challenge for SCR retrofit is to minimize the capital requirement while the challenge for SNCR is to minimize the reagent requirements. Designing hybrid SNCR/SCR systems suggests optimization of these costs over the lifecycle for a specific level of NO_x reduction.

Chemical Utilization

In post-combustion NO_x control processes, NO_x reduction is achieved at a given Normalized Stoichiometric Ratio or NSR. Simply put, NSR refers to the ratio of chemical reductant applied to the amount of NO_x existing in the flue gas. With SCR, ammonia is typically the reductant and is typically applied at an NSR of one for deep reductions. In other words, on mole of NH_3 applied per mole of NO_x. If only a 75% NO_x reduction was required, the NH_3 NSR would be approximately 0.75. In non-catalytic systems, the reductant is applied in broader ranges of NSR because of relatively lower NO_x reduction efficiency compared to catalytic systems. In commercial practice, NSRs range from 0.6-2.0. When urea is used for SNCR systems, an NSR of 1.0 means 0.5 mole of urea is applied for 1.0 mole of NO_x, because urea has two nitrogen moieties for reaction with NO_x. Chemical utilization is a quantification of NO_x reduction efficiency expressed by:

$$\frac{NO_x \text{ Reduction } \%}{NSR}$$

In other words, if each l-mole of injected urea or ammonia reduces NO_x to the theoretical maximum amount, utilization is 100%. One hundred percent chemical utilization is approached in SCR systems, but in a SNCR system, values range from 30-60%. In commercial post-combustion NO_x control systems, maximizing utilization, all other things being equal, minimizes lifecycle operating costs.

Figure 2 schematically depicts the enabling effect of downstream catalyst on SNCR performance in a hybrid system. SNCR NO_x reduction occurs in a defined temperature window, roughly bell-shaped with maximum SNCR NO_x reduction occurring at the top, or plateau of the bell. In a commercial “stand-alone” SNCR system, performance is optimized by operating on the right side of the slope in the temperature window curve[2] (in Area A). In this region, the hot side of the performance maximum, ammonia slip is very low or nonexistent. This is often an operating constraint imposed by the source owner. In contrast, the SNCR component of the hybrid system operates best at the plateau which is lower temperature. In this region (Area B), SNCR NO_x reduction is higher and some ammonia slip is produced. The ammonia slip is available to reduce NO_x in a catalyst system downstream. When operated in this manner, SNCR NO_x reduction is maximized (compared to its stand-alone performance) and additional NO_x reduction occurs in the catalyst portion, fueled by the generated ammonia slip.

Hybrid systems can be designed to operated in the cooler zone (Area C) on the left side of the slope. This will produce more ammonia slip than the other regions. In this scenario, SNCR NO_x reduction is less than maximal and SCR NO_x reduction increases until limited by catalyst space velocity. Overall system NO_x reductions beyond 75% would typically require this type of operation and require catalyst reactor dimensions that would not be possible to fit in existing duct space. Hybrid systems can be designed to maximized SNCR Performance while "existing duct" SCR controls the ammonia slip (Area B). Reagent utilization for NO_x reduction can increase dramatically compared to stand-alone SNCR.

RESULTS

This project is presently in the design and construction phase. It is scheduled to be in operation by October of 1997 and final tuning completed by the beginning of November. A final report will be produced by the end of 1998 to detail the results of the demonstration.

APPLICATION

The use of Hybrid SNCR/SCR systems permits "tailoring" NO_x reduction and lifecycle cost to the potentially complex future requirements of NO_x reduction for ozone mitigation. The total lifecycle cost of the modified SNCR/SCR NO_x reduction process is a function of chemical utilization, catalyst size and capital requirement. Very high NO_x reductions (above 90%) require a substantial catalyst volume. This system cannot be placed in existing or expanded duct dimensions and will always require, at the very least, major modifications. A modified SNCR/SCR system, providing between 50-60% precatalytic reduction, would require between 75-80% further NO_x reduction to achieve 90% overall. This would still demand 88% of the original catalyst volume. Similarly, for an overall NO_x reduction of 75%, a stand-alone SCR system requires approximately 88% of the original high NO_x reduction catalytic volume.

A modified SNCR/SCR process would conceptually be effective for approximately 75% overall NO_x reduction. Precatalystic SNCR reduction of 50-60% requires only 38-50% SCR reduction, and no more than half of the original catalyst volume as designed for 90% reduction. This is also only 57% of the catalyst volume required for stand-alone SCR targeted at 75% reduction. An "In-Duct" catalyst may be used on a site-specific basis to fulfill this half-sized volume requirement.

The Seward Unit #5 Hybrid SNCR/SCR is designed with the intent to reduce lifecycle operating cost by increasing reagent utilization at modest catalyst capital requirement. The introduction of a catalyst allows the SNCR system to achieve a 53% reduction with 18-20 ppm of ammonia slip. The slip acts as the reducing agent for the SCR which strips the ammonia from the flue gas while contributing an additional 6.3% NO_x reduction. The resulting overall NO_x reduction for the system becomes 56.7%. Table 1 details the design data for the two catalyst that are being evaluated for this project.

REFERENCES

1. Jantzen, T. and Zammit, K., “Hybrid SCR,” presented at EPRI/EPA NO_x Symposium, Kansas City, 1995.
2. U.S. Patent 4,780,289, issued 1988.

TABLE 1. PROCESS DESIGN*

DESCRIPTION	UNITS	CATALYST 'A'	CATALYST 'B'
Flue Gas Flow	SCFH-wet	19,387,898	19,387,898
Baseline NO_x	ppmvdc	533	533
	lb/MMBtu	0.75	0.75
	lb/hr	1,093	1,093
NO_x after SNCR	ppmvdc	256	256
	lb/MMBtu	0.36	0.36
NO_x Reduction	%	52	52
Chemical Utilization	%	40	40
NSR		1.35	1.35
Ammonia Flow	lb pure/hr	1,000	1,000
Final NO_x Desired	ppmvdc	240	238
Overall Reduction	%	55	55.3
SCR Reduction	%	6.3	7
NH_3 at Catlayst Entrance	ppmvdc	18	20
NH_3 Slip Requirement	ppmvdc	2	2
Normalized Reactivity		0.68	0.98
Space Velocity	1/hr	11,091	16,147
Specific Area	m^2/m^3	509	550
Area Velocity	m/hr	21.8	29.4
Catalyst Volume	ft^3	1,748	1,200
	m^3	49.5	34
Actual Duct Area	ft^2	588	563
Catalyst Depth	ft	4.53	2.5
	m	1.38	0.76
Gas Temperature (design)	^oF	600	600
Flow @ Design Temp.	ACFH	38,944,897	38,944,897
Face Velocity	ft/s	18.4	19.2
Delta P	in H_2O	1.7	1
Final NO_x	ppmvdc	240	238
	lb/MMBtu	0.337	0.335

* This table is base on one catalyst vendor for the complete Hybrid SNCR/SCR. The demonstration will include one catalyst in duct 'A' and one catalyst in duct 'B'.

Figure 1. Hybrid SNCR/SCR yields improved SNCR performai
Total reagent utilization approaches 100%.

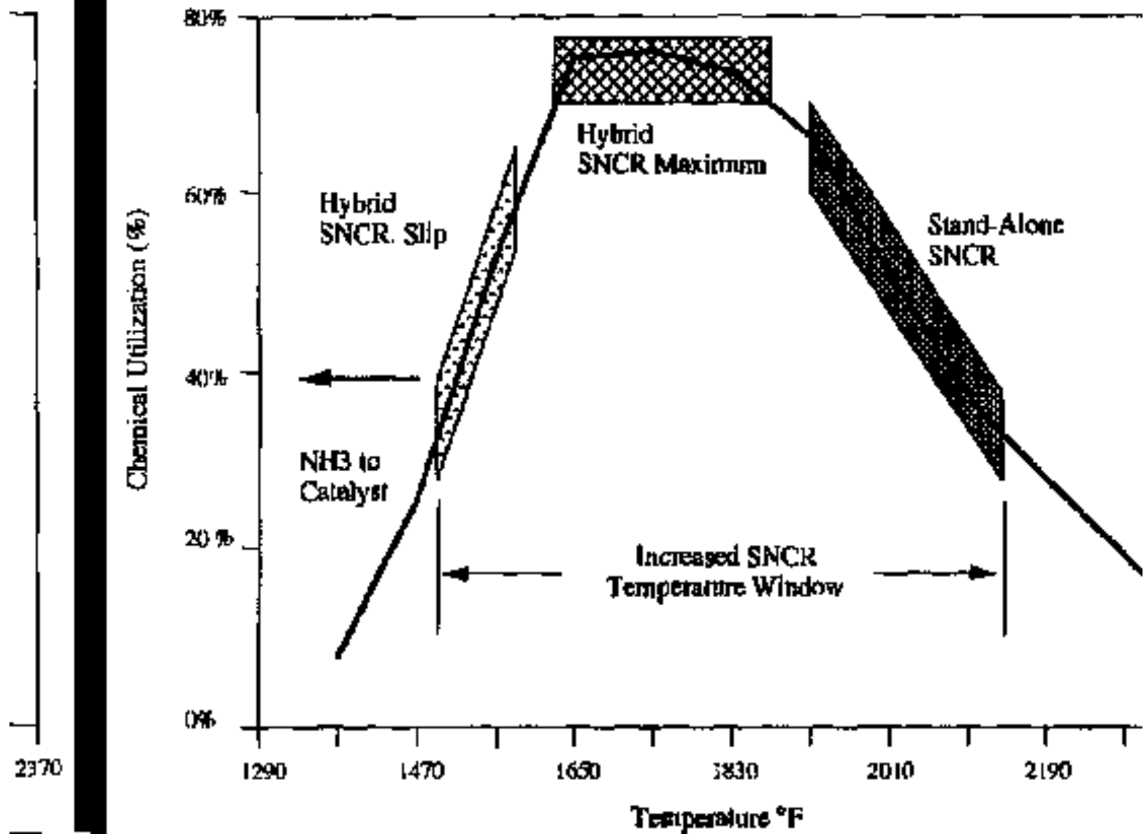
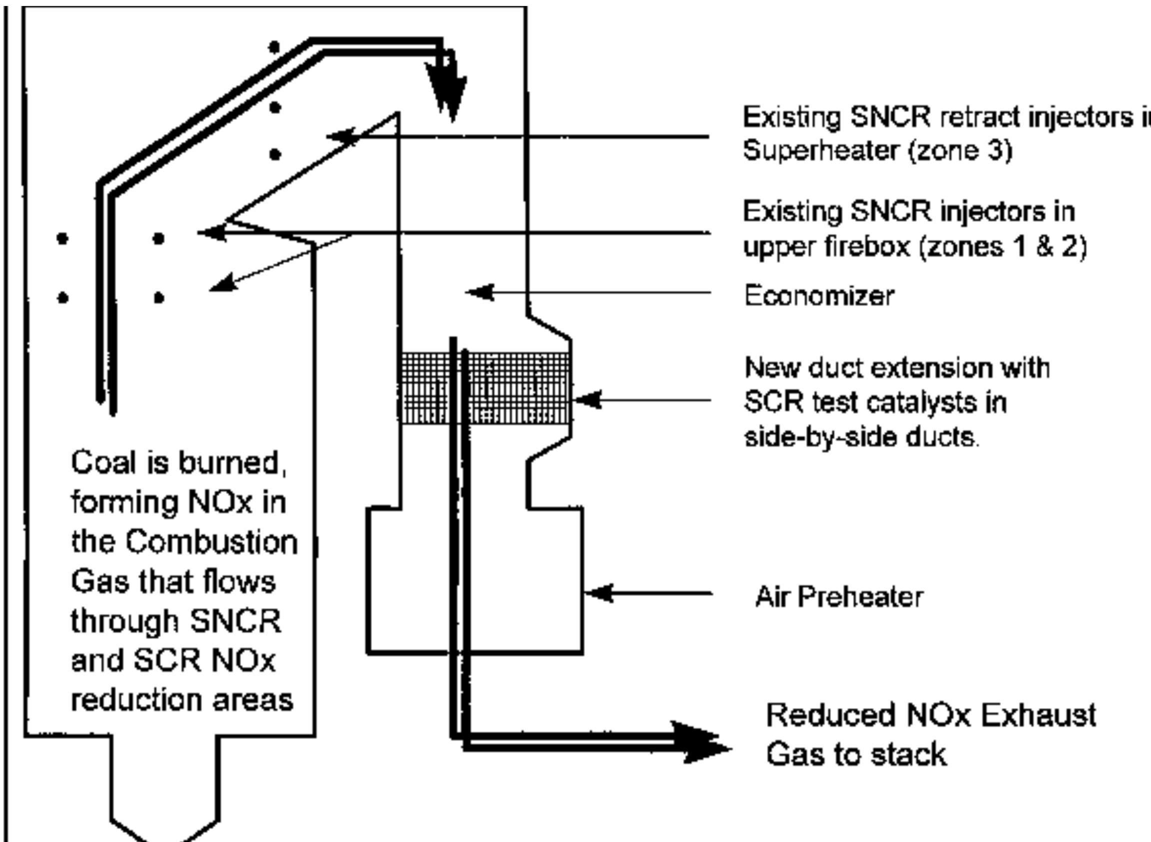


FIGURE 2



SNCR/SCR Hybrid Retrofit
Seward Station #15 Boiler